

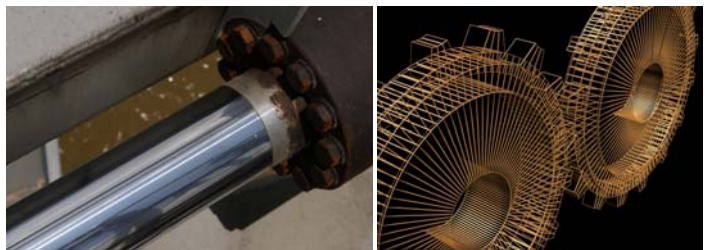
NA-LUBE[®]

KR Series

Alkylated Naphthalenes



Synthetic Base Oils / Base Oil Modifiers
for Superior Thermo-oxidative Stability



NA-LUBE[®] KR Series Alkylated Naphthalenes Synthetic Base Oils and Base Oil Modifiers

King's KR Series offer today's formulators the widest range of alkylated naphthalenes for use as base stocks or modifiers for non-polar base stocks for lubricants requiring:

- Superior thermo-oxidative stability
- Excellent hydrolytic stability
- Improved additive stability
- Excellent seal swell characteristics

With decades of experience in the alkylation of naphthalene, King not only offers a range of products as shown below but can work with you to develop customized products for your particular needs.

KR Series - Typical Properties

Property	Test Method	KR-007A	KR-007	KR-010	KR-015	KR-019
Kinematic Viscosity @ 40° C	ASTM D 445	21.8 cSt	35.5 cSt	72.1 cSt	114 cSt	177 cSt
Kinematic Viscosity @ 100° C	ASTM D 445	3.8 cSt	5.5 cSt	9.2 cSt	13.5 cSt	18.7 cSt
Viscosity Index	Calculated	22	85	103	110	118
Aniline Point	ASTM D 611	40°C	50°C	60°C	94°C	103°C
Noack Volatility, Wt. %	CEC L40	39%	30%	11%	2.2%	1.4%
Pour Point	ASTM D 97	-48°C	-48°C	-48°C	-39°C	-26°C
Flash Point	ASTM D 92	206°C	210°C	220°C	260°C	285°C

Applications

From the most demanding applications for superior thermo-oxidative stability to improving the performance of Group II and III non-polar base oils, KR Series products are being used as both specialty fluids and as modifiers for base oils. The table below shows application areas and general product recommendations.



APPLICATION	KR-007A	KR-007	KR-010	KR-015	KR-019
Automotive Lubricants					
		= Recommended			
Crankcase Oils					
Automatic Transmission Fluids					
Industrial Lubricants					
Compressor Oils					
Gear Oils					
General Industrial Lubricants					
Grease					
Hydraulic Fluids					
Turbine Oils					

KR-Series Property Comparison to Other Base Fluids

King alkylated naphthalenes typically offer superior thermo-oxidative stability while maintaining good to excellent ratings for other properties.

Property	NA-LUBE KR Series	PAO	Esters	Mineral Oils (Group II & III)
Thermo-oxidative Stability	Excellent	Good	Good to Excellent	Good
Thermal Stability	Excellent	Excellent	Excellent	Excellent
Hydrolytic Stability	Excellent	Excellent	Poor	Excellent
Seal Swell	Good to Excellent	Poor	Excellent	Poor
Viscosity Index	Good	Excellent	Excellent	Good to Excellent
Additive Solubility	Good to Excellent	Poor	Excellent	Poor

Formulating Performance

■ Aniline Point and Additive Solubility (ASTM D 611)

Aniline point is an indirect measure of the polarity of a substance and its ability to solubilize polar materials. As shown below, the KR Series offers a range of aniline points from 40°C to 103°C covering a broad spectrum of polarity/solubility options.

<i>More Polar</i>	RELATIVE ANILINE POINTS					<i>Less Polar</i>
Monoesters Diesters Polyol Esters	KR-007A	KR-007	KR-010	KR-015	KR-019	PAO Group II and III Mineral Oils
-7 to 5°	40°C	50°C	60°C	94°C	103°C	125°C

■ Solubility Comparison - Silicone Fluids

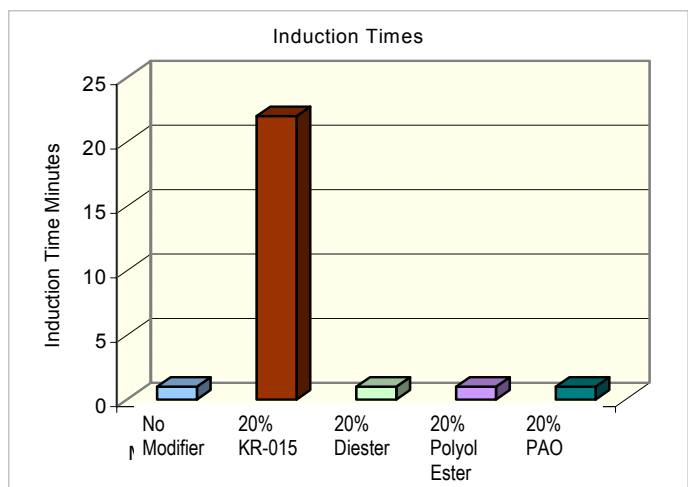
Typically silicone fluids have poor solubility. As shown in the chart below a range of KR series were tested for their ability to enhance the solubility characteristics of four different silicone fluids.

Solubility Comparison - Enhancer for Silicone Fluids				
Silicone Fluid Tested	Dimethyl Silicone (50 cPs)	Methyl Phenyl Silicone Fluids - Various Phenyl Content		
		(5% phenyl content) 100 cPs	(25% phenyl content)	(50% phenyl content)
NA-LUBE KR-019	Insoluble	Insoluble	Insoluble	Insoluble
NA-LUBE KR-015	Insoluble	Insoluble	Soluble	Soluble
NA-LUBE KR-007A	Soluble	Soluble	Soluble	Soluble

■ **Thermal-Oxidative Stability**
(PDSC - Pressure Differential Scanning Calorimetry)
 Comparison of Modifiers for Group III Base Oils

The chart to the right shows oxidative induction times for 20% blends of various synthetic base oils in a 7 cSt Group III oil. As can be seen, KR-015 significantly outperformed the other fluids tested including PAO, Diester and Polyol Ester base oils.

Oxidation Induction Times
 (Isothermal at 160°C and 150 psi)



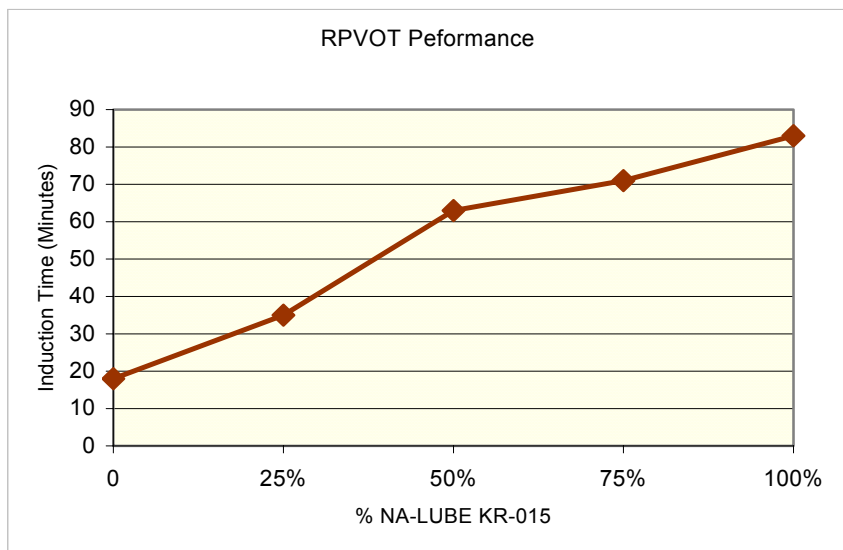
Additionally, when KR-015 and KR-019 were tested (neat -100%) at 200°C and 210°C with 500 psi O₂, the results were:

PDSC Induction Time	KR-015	KR-019
Minutes @ 200°C	22	10
Minutes @ 210°C	9	4

■ **Thermal-Oxidative Stability** *(RPVOT - ASTM D 2272)*
 Rotating Pressurized Vessel Oxidation Test - 90 psi O₂ @ 150°C

KR-015 was tested at various modification levels in a 7 cSt Group III Base Oil to track its influence on RPVOT performance.

As shown to the right, KR-015 can impart dramatic improvements in thermo-oxidative stability when used as a base oil modifier. All tests were performed on the base oils without the addition of additives or stabilizers.



Also, NA-LUBE KR-015 and NA-LUBE KR-019 have excellent thermo-oxidative stability as 100% fluids with and without additives, as shown below:

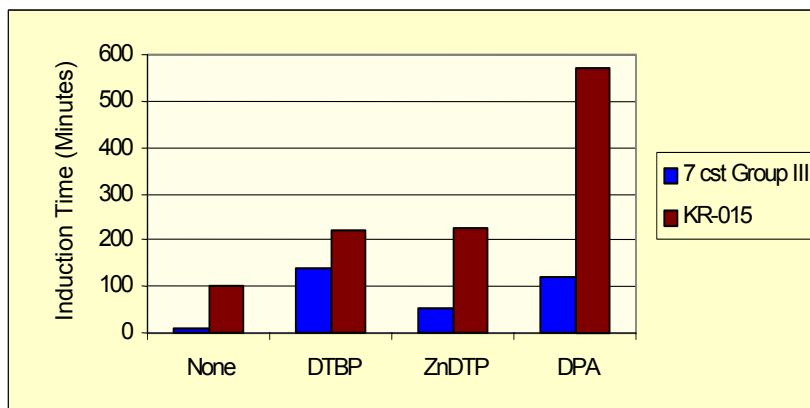
BASE FLUID	KR-015		KR-019	
	Neat Fluid (100%)	With 1.9% IGO*	Neat Fluid (100%)	With 1.9% IGO*
Minutes to pressure drop of 25.4 psi	89.69	567.75	60.65	647.94

* IGO = Non-EP Industrial Gear Oil Package containing antioxidant, antiwear additive and yellow metal deactivator

■ Antioxidant Effect on Thermal-Oxidative Stability of Base Oils

(RPVOT - ASTM D 2272) Rotating Pressurized Vessel Oxidation Test - 90 psi O₂ @ 150°C

Both KR-015 and a 7 cst Group III oil were tested in the RPVOT procedure to determine the effect of adding 0.2% of various antioxidants to the base oils. As shown in the graph to the left, significant improvements to the thermal oxidative stability (induction time) were obtained using the KR-015.



■ Cincinnati Milicron Thermal Stability Test (Modified - higher temperatures, 200°C & 225°C)

This test is used to evaluate the thermal stability of fluids in the presence of copper and steel at elevated temperatures for 168 hours. Normally, run at 135°C, the two KR products and a PAO were tested at elevated temperatures (200°C and 225°C) both neat and with an antioxidant package containing an antioxidant and a yellow metal deactivator. Not surprisingly due to breakdown and polymerization, the PAO experienced a very high viscosity increase.

BASE FLUID	Neat Fluid @ 200°C		Neat Fluid @ 225°C		Base Fluid with 1.5% AOP** @ 225°C	
	Total Sludge (mg/100ml)	% Viscosity Increase	Total Sludge (mg/100ml)	% Viscosity Increase	Total Sludge (mg/100ml)	% Viscosity Increase
KR-015	2.85	8.36	19.98	20.32	8.15	19.69
KR-019	6.30	10.08	2.80	35.43	25.5	21.43
PAO*	2.15	100.67	13.65	332.75	8.10	163.92

* PAO - 114 cSt @ 40°C - Blend adjusted to equal viscosity ** Antioxidant Package containing an antioxidant and yellow metal deactivator

■ Thermal Stability (FTM-3411 - Fully formulated 7 cSt Group III Base Oil)

When tested in the Federal Test Method 3411 for Thermal Stability (274°C for 96 hrs.), NA-LUBE KR-015 showed exceptional thermal stability as demonstrated in the chart below. At 20% modification of a 7 cSt Group III base oil, KR-015 exhibited excellent performance while comparable systems containing esters resulted in thick, dark deposits and in one case, extensive degradation of the metal.

In general, all alkylated naphthalenes have superior thermal stability than other base stocks at higher temperatures (over 200°C).

PRODUCT	20% KR-015	20% TMP Ester	20% Diester	7 cSt Group III	KR-019*
Percent Change in Viscosity	-0.80	-10.02	-15.78	-0.86	-1.32
Change in Acid Number	-0.03	5.97	0.52	0.03	0.03
Change in Metal Weight, mg/cm ²	-0.008	-2.97	0.05	0	0
Metal Appearance	Shiny	Etched	Blue-Black Shiny	Gold Shiny	Dull Blue-Black
Oil Appearance	Light Amber	Black	Very Dark Amber	Clean	Light Yellow
Test Cell Appearance	Clean	Heavy Black Stains	Clean	Clean	Clean

* KR-019 as 100% fluid

High Temperature Volatility

■ NOACK Volatility (CEC L40, DIN 51581, 250°C)

The KR Series performance in the NOACK Volatility Test ranges from 1.4% loss to a high of 39%. KR-010 at 11% is an ideal candidate for the new standards for ILSAC GF-3 oils limiting loss to under 15%.

KR Product	KR-007A	KR-007	KR-010	KR-015	KR-019
Noack Volatility, Wt. %	39%	30%	11%	2.2%	1.4%

■ Thin Film Volatility (2 grams of fluid in aluminum pan, weight loss after 24hrs. at temperatures shown)

As shown below lower viscosity products such as PAO yield higher volatility than higher viscosity products such as KR-019.

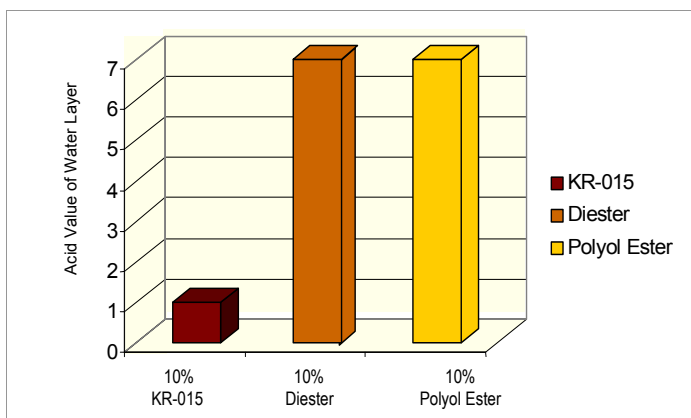
BASE FLUID	Neat Fluid - Weight Loss, %		
	200°C	225°C	250°C
NA-LUBE KR-015	12	26.7	67.4
NA-LUBE KR-019	6.7	12.6	39.4
PAO*	41.1	50.6	65.1

* PAO - 114 cSt @ 40°C - Blend adjusted to equal viscosity to KR-015

■ Hydrolytic Stability - Fully Formulated ISO 46 Group II Base Oil (ASTM D 2619)

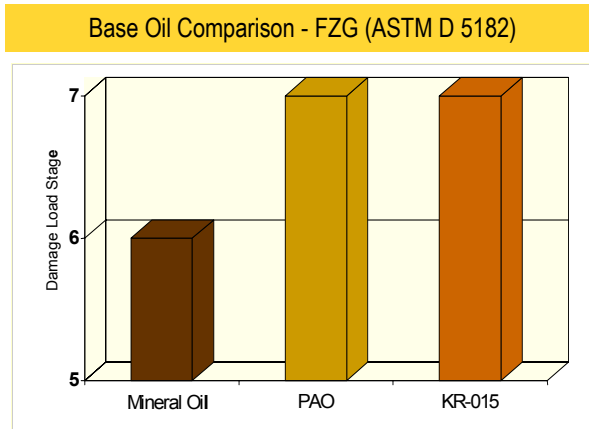
The KR Series offers excellent hydrolytic stability. The chart to the right shows the affect of a 10% modification of an ISO 46 Group II Base Oil with KR-015. Below shows ASTM D 2619 performance for KR-15 and KR-019 as neat fluids (100%).

NA-LUBE (Neat 100%)	KR-015	KR-019
Hydrolytic Stability TAN Increase, mg KOH / g	0.02	0.02



■ FZG Study (ASTM D 5182) Systems Adjusted to Equal Viscosities

KR-015 was compared to traditional Mineral Oil and PAO base stocks for relative lubricity properties as measured by FZG damage load stages when adjusted to equal viscosities. As expected, KR-015 outperformed the Mineral Oil and gave similar lubricity characteristics as the PAO.



■ **Wear Characteristics (ASTM D 4172)**

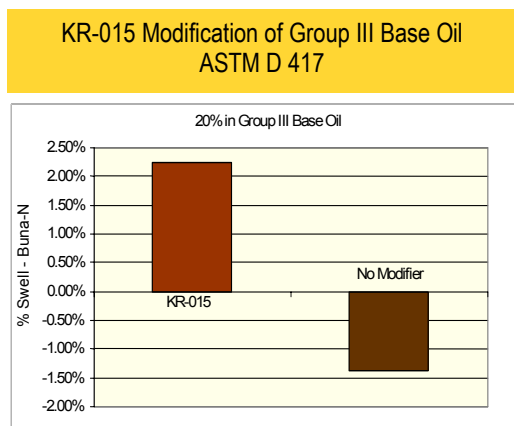
NA-LUBE KR-015 and KR-019 were compared to an ester and PAO base stock in the Four Ball Wear Test - ASTM D 4172 (75°C, 1800 rpm, 3 kg) . As can be seen to the right, The KR Series products and PAO gave similar performance at 100%, outperforming the ester base oil. With the addition of an Industrial Gear Oil package, all fluids gave similar performance.

Base Fluid	Neat - 100%	With 1.9% IGO*
KR-015	0.65	0.30
KR-019	0.60	0.30
Ester	0.90	0.35
PAO	0.50	0.30

* IGO = Non-EP Industrial Gear Oil Package

■ **Seal Swell Properties (ASTM D 417 and ASTM D 4298)**

KR Series products will impart seal swell properties to non-polar base oils. For example the chart below left shows the improvements achieved with 20% modification of a 7 cSt Group III oil with KR-015 in the ASTM D 417 test. The table below right shows the affect of 100% KR-019 on three different seal materials in the ASTM D 4298 test.



**NA-LUBE KR-019
SEAL SWELL ASTM D 4298**

Seal Type	Chloroprene 240 hrs @ 100°C	Fluorocarbon 240 hrs @ 150°C	Nitrile Butadiene 240 hrs @ 150°C
Volume Change, %	11.2	0.1	3.8
Points Hardness Change	-5	-2	-1

CONTACT INFORMATION

For additional information, samples and/or technical assistance, please contact King Industries at (800) 431-7900 in the U.S. or as follows:

World Headquarters

King Industries, Inc
Science Rd., Norwalk, CT 06852
Phone: 1-800-431-7900 or (203) 866-5551
Fax: (203) 855-6619
Email: info@kingindustries.com



www.kingindustries.com

European Sales Office

King Industries, Inc
Noordkade 64
2741 EZ Waddinxveen
The Netherlands
Phone: 0182-631360; Fax: 0182-621002
Email: info@kingintl.nl



The conditions of your use and application of our products, technical assistance and information (whether verbal, written or by the way of product evaluations), including any suggested formulations and recommendations, are beyond our control. Therefore, it is imperative that you test our products, technical assistance and information to determine to your own satisfaction whether they are suitable for your intended uses and applications. Such testing has not necessary been done at King Industries, Inc. ("King"). The facts, recommendations and suggestions herein stated are believed to be reliable, however, no guarantee or warranty of their accuracy is made. EXCEPT AS STATED. THERE ARE NO WARRANTIES, EXPRESSED OR IMPLIED, OF MERCHANTABILITY, FITNESS OR OTHERWISE. KING SHALL NOT BE HELD LIABLE FOR SPECIAL, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES. Any statement inconsistent herewith is not authorized and shall not bind King. Nothing herein shall be construed as a recommendation use any product(s) in conflict with patents covering any material or its us. No license is implied or granted under the claims of any patent. Sales or use of all products are pursuant to Standard Terms and Conditions stated in King sales documents.

KRSERIES-112004